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(54) Electro-hydraulic actuator

(57) An electro-hydraulic valve actuator comprising an actuator casing, a piston/rack means (5) in the casing; an output shaft (22) in communication with the piston/rack means (5) for driving a valve, the output shaft (22) effecting rotational movements in response to the linear movements of the piston/rack means (5); resilient return means (1) biasing the reciprocating walls (25) of the piston/rack means (5) to a closed position; a pumping means (8); and a fail-safe solenoid valve system. Upon loss of power to the actuator, the fail-safe solenoid valve (29) opens to thereby cause the resilient return means (1) to force hydraulic fluid out of the centre chamber (24) through the primary and secondary internal flow paths (27 and 28), into at least one of the outside chambers (35), so that the piston/rack means(5) is returned to a closed position for rotating the output shaft (22) to drive the valve.

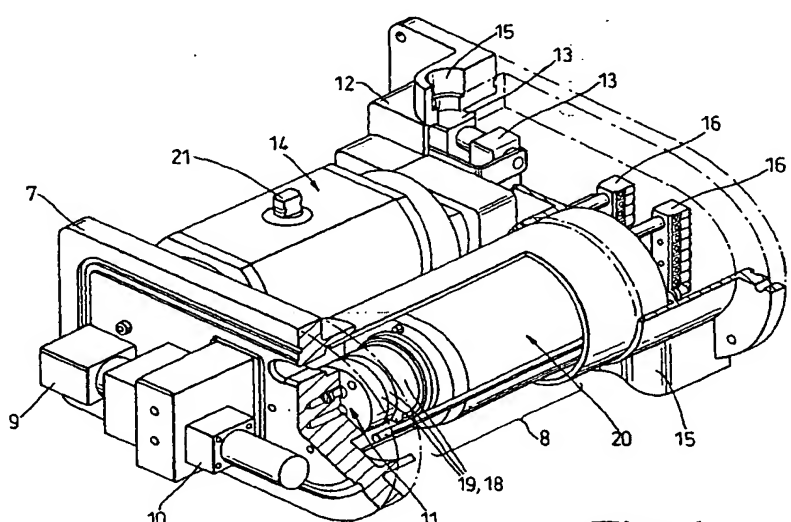

Fig. 1

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Description

[0001] This invention relates generally to an electro-hydraulic actuator, and particularly to a fail-safe electro-hydraulic valve actuator.

[0002] It is desirable for electrically operated valves in operating facilities in chemical, petrochemical and power industries to be provided with fail-safe mechanisms to open or close upon loss of electrical power or instrument control signal at the actuator. In various types of piping systems in these facilities, it is even essential to have valves fail in a "safe" position for safety, to avoid system damage, or to avoid loss of chemicals. For example, in many systems, hazardous chemicals must be contained or controlled, or reactions must be prevented or stopped, in the event of system failure. There are many types of fail-safe valve systems known in the art, such as electro-pneumatic, electro-hydraulic and electro-mechanical systems.

[0003] One type of electro-mechanical system known in the art comprises an electric valve actuator and a spring return mechanism. This actuator uses a motor and gearbox to actuate a valve and to wind up a spring which reverses upon loss of electrical signal or power to the actuator. The actuator can operate to hold the spring in the open position continuously or to actuate the spring with every turn. Actuators which energize the spring during every actuation have a disadvantage of increasing the power requirements to run the actuator motor to twice that required to run a motor of an actuator not having a fail-safe mechanism. If the spring is instead continuously held in the energized position, it is not exercised until it is called upon to actuate the valve, thus increasing the likelihood of sticking components and actuator malfunction.

[0004] Alternatively, electric valve actuators use a battery backup to reverse actuator direction when a loss of power is detected at the actuator. However, batteries will only actuate the valve a limited number of times depending on the storage potential of the battery and the power requirements of the actuator. Failure to maintain the battery charged and in good working order will negate the fail-safe feature of the actuator.

[0005] A third way of providing fail-safe mechanisms for electrically actuated valves is to use a spring return arrangement whereby fluid is pumped into a chamber by a hydraulic pump driven by an electric motor. The fluid moves a piston(s) and rotates the output shaft, while compressing and energizing the return spring(s). An electrically controlled solenoid valve maintains the pressure developed in the chamber. Upon loss of power or electrical signal, the solenoid valve is opened which allows the spring(s) to return the fluid from the pressurized chamber to the non-pressurized reservoir.

[0006] Examples of prior art electro-hydraulic valve actuators with spring returns are disclosed in US patent 4,132,071, UK patent 2,005772 and Canadian patent 2,202,821. These electro-hydraulic actuators operate in similar manners whereby hydraulic fluid is pumped into a chamber which moves a piston against a spring. Release of the pressure allows the spring to return the piston and move the fluid from the pressurized centre to the un-pressurized end cap or spring housing.

[0007] Prior art electro-hydraulic actuators such as those mentioned above have several disadvantages, including: 1) using scotch yoke and spur gear systems with a piston rod for changing linear motion in the actuator to rotary output motion, thus limiting rotary motion to a maximum of 90 degrees; 2) using external conduits which are susceptible to freezing, breakage and leakage; 3) using external cylinders to house fail safe springs, thus requiring rod spring guide systems to ensure linear compression of the spring without distortion; and 4) using only one solenoid valve for both fail-safe operation and position controlling.

[0008] It is an object of the present invention to provide an electro-hydraulic actuator which does not suffer from, or suffers less from, the aforementioned disadvantages.

[0009] In accordance with the present invention an electro-hydraulic actuator comprises an actuator casing and a piston/rack means within the casing having walls reciprocating linearly to effect linear movements, the reciprocating walls defining a centre chamber therebetween and two outside chambers inside the casing. An output shaft is in communication with said piston/rack means for driving a valve, the output shaft effecting rotational movements in response to the linear movements of said piston/rack means. A resilient return means is provided which engages the reciprocating walls of the piston/rack means and inner end walls of the casing, and biases the reciprocating walls of the piston/rack means to a closed position.

[0010] The actuator further includes a pumping means and preferably a check valve located at the outlet of the pumping means. A primary internal flow path is provided for transferring fluid from the pumping means to a first output port and into the centre chamber, wherein the fluid causes the piston/rack means to expand on the casing and transmit linear motion of the piston/rack means to the output shaft.

[0011] A fail-safe solenoid valve system is further provided comprising a secondary internal flow path connecting to and extending from the primary internal flow path to a second outlet port opening into at least one of the outside chambers, and a normally closed solenoid valve in the secondary flow path preventing flow through the secondary flow path wherein, upon loss of power to the actuator, the solenoid valve opens allowing the resilient return means to force fluid out of the centre chamber, through the primary and secondary internal flow paths, and into at least one of the outside chambers, and to return the piston/rack means to a closed position, thereby rotating the output shaft in communication with a device to be turned.

[0012] Preferably, the piston/rack means is capable

of transmitting enough linear movement so that the output shaft can rotate up to 360 degrees.

[0013] Further, the electro-hydraulic actuator may comprise at least one internal guide rod for guiding the linear motion of the piston-rack means in the casing, wherein, preferably, at least one of the internal guide rods contains the first output port from the primary flow path and fluid flowing to and from the primary flow path to the centre chamber flows through the internal guide rod and the first output port in said internal guide rod.

[0014] A positioning solenoid valve system may be provided including a tertiary internal flow path connecting to and extending from said primary internal flow path to said second outlet port and a normally closed positioning solenoid valve in said tertiary flow path preventing flow through said tertiary flow path wherein, to partially close said actuator piston/rack means, said positioning solenoid valve is opened buy a positioning controller allowing said resilient return means to force fluid out of said centre chamber, through said primary and tertiary internal flow paths, and into at least one of said outside chambers and to move said piston/rack means to a partially closed position whereby said positioning controller closes said positioning solenoid valve. The positioning solenoid valve preferably has a smaller flow capacity than said fail-safe solenoid valve.

[0015] One or more push rods may be provided for monitoring the position of said piston/rack means and a limit switch may be provided for stopping pumping of the pumping means when the push rod indicates said piston/rack means is fully open.

[0016] One embodiment of the invention will now be described by way of example only with reference to the accompanying drawings of which:-

Figure 1 is a perspective view of an electro-hydraulic actuator according to the present invention;

Figure 2a is a perspective cut away view of the hydraulic piston assembly of the actuator showing the position of the piston/rack means when the actuator is pressurized;

Figure 2b is a perspective cut away view of the hydraulic piston assembly of the actuator showing the position of the piston/rack means when the actuator is unpressurized;

Figure 3 is a side view of the casing of an actuator according to the present invention;

Figure 4 is a sectional view of Figure 3 taken at section line 1-1 and showing internal components of an actuator according to the present invention; and

Figure 5 shows a flow path schematic of the hydraulic fluid in internal casted flow paths of an actuator according to the present invention.

[0017] Figure 1 shows a preferred embodiment of an electro-hydraulic actuator according to the present invention. The actuator has no external plumbing connections which are susceptible to freezing, breakage, leakage associated with tubing connections and hydraulic joints. The actuator is completely self-contained and uses internal cast flow paths to move fluid to and from the various operating components of the actuator. The actuator has no atmospheric vented reservoir and can be mounted in any orientation.

[0018] The actuator preferably comprises a pump and motor assembly 8 including a gerotor positive displacement pump element 18 (not shown in Figure 1), plates to house the gerotor 19 and a motor 20 close coupled to the gerotor 19 to turn the gerotor 19 and create pumping action. A gerotor positive displacement pump element advantageously provides faster operational speeds than hydraulic units using a spur gear or a diaphragm pump.

[0019] A pump end casing 7 provides a mount for the pump and motor assembly 8, solenoid valve 10 and optional solenoid valve 9, and also provides a mechanism for fluid transfer within the actuator including to and from solenoid valves 9 and 10 and the pump and motor assembly 8. The pump end casing preferably also includes a one-way check valve 11 to prevent back flow into the pump.

[0020] As shown in Figure 4, the hydraulic piston assembly of the actuator preferably comprises piston return springs 1, piston/rack 5, internal guide rods 4, a splined output shaft 22, and output shaft connections 21 (see Figure 3). As shown in Figures 2a and 2b, the output shaft connections 21 are connected to output pinion 6 and are concentrically surrounded by hydraulic pinion seals. Pinion 6 is connected to a device to be turned, such as a valve. However, the actuator of the present invention can also be used for operating a damper, louvre or other device which require a rotary motion to effect a change in operation.

[0021] The hydraulic piston assembly is operated by fluid pressure entering the assembly from the pump end casing 7 through output port 23 preferably located in one of the internal guide rods 4 and into centre chamber 24 between piston/rack walls 25. As the pressure increases, the centre chamber 24 fills with fluid and presses piston/rack walls 25 outward against the action of return springs 1. Internal guide rods 4 keep the piston/rack 5 square to the pinion 6 during movement. As piston/rack walls 25 move outward, teeth 26 on the piston/rack 5 engaging corresponding teeth on the output shaft 22 turn the output shaft 22 and pinion 6 (shown in Figure 2a). The pinion 6 is connected to a valve (not shown) and the turning action of the pinion 6 is transmitted to a valve by any number of means known in the prior art.

[0022] A limit switch end casing 12 houses limit switches 13 and connecting push rods 14 which monitor the piston position and control the actuator when it reaches full stroke. When the actuator reaches its fully

open position, connecting push rods 14 are displaced toward the limit switch end casing 12 which activates the limit switches 13. The limit switches 13 then shut down the pump and motor. No external gearing, cams or rods are used. Conduit connections 15 and terminal strips 16 are also provided for wiring the motor, position control electronics, or for providing a drain port if desired.

[0023] The operation of the fail-safe mechanism will now be described. An in-line check valve 11 is positioned at the outlet of pump and motor assembly 8 to prevent back flow of fluid into the pump and motor assembly 8 when not operating (see Figures 1, 4 and 5). As shown in the fluid flow schematic of Figure 5, fluid is pumped from the check valve 11 through flow path 27 to the hydraulic piston assembly and through port 23 (see Figure 4) in internal guide rod 4 to operate piston/rack 5 as discussed above with reference to Figure 4. Alternative flow path 28 leads to solenoid valve 29, the "fail-safe" solenoid valve (shown in a "closed" position).

[0024] In systems with only one solenoid valve, when the actuator is energized, solenoid valve 29 is closed, and hydraulic fluid flows only to the hydraulic piston assembly. If there is loss of power to the actuator, or the actuator is deenergized, solenoid valve 29 opens allowing the return springs 1 to force fluid to move out of the centre chamber 24 and rotate pinion 6 to the "fail-safe" position. The fluid forced out of the centre chamber 24 flows through paths 27 and 28 to path 30 (see Figure 5) into the hydraulic piston assembly and through port 34 (see Figure 4) into an outside chamber 35 as shown in Figure 4.

[0025] Preferably, the electro-hydraulic actuators of the present invention have two solenoid valves which operate independently from one another. However, a person skilled in the art can readily apply the principles of the invention to actuators having three or more solenoid valves. As discussed above, solenoid valve 29 is used for "fail-safe" operation. In the event of power failure, or power shut off to the actuator, solenoid valve 29 opens and allows the return springs 1 to force the actuator into a "fail-safe" position. Means for signalling the solenoid valve 29 to open upon power failure are well known in the art.

[0026] Positioning solenoid valve 31, as shown in Figure 5, is connected to flow path 27 by flow path 32, on either side of where flow path 28 connects to flow path 27. Positioning solenoid valve 31 is normally closed and is used in conjunction with a positioning controller (not shown) mounted to the actuator for intermediate actuator positioning. Positioning solenoid valve 31 preferably has a smaller capacity than the "fail-safe" solenoid valve to allow for finer control of the speed and positioning of the actuator to avoid overshoot.

[0027] When power is applied to the unit, the positioning solenoid valve 31 and fail-safe solenoid valve 29 are closed and remain closed until some further change in the system. To open the actuator to an initial position not fully open, the controller limits the power to the motor to that necessary to open the actuator to the particular position for which the controller is set. The check valve 11 maintains the required fluid pressure to hold the actuator at the desired position. To further open the actuator to a different position, the motor is started and the controller provides increased power to the motor to push more fluid into the centre chamber 24.

[0028] To partially close the actuator to a different position, the controller sends a signal to the positioning solenoid valve 31 to open the positioning solenoid valve 31 allowing the return springs 1 to force fluid to move out of the centre chamber 24 through paths 27 and 32 to path 30 and through port 34 into the hydraulic piston assembly in an outside chamber 35, outside of the rack/piston walls 25. See Figures 4 and 5. Once the actuator has reached the desired position, the positioning solenoid valve 31 is closed to maintain the actuator in the desired position.

[0029] Figure 4 shows a top view of the internal flow paths as they are preferably contained within the actuator casing, with flow path 27, containing check valve 11, being located directly above flow path 30 (see also Figure 1), and flow paths 32 and 28 being located in the same vertical plane within the actuator casing.

[0030] The positioning controller can be any one of various types of market-available positioning devices capable of controlling at voltages compatible with motor and solenoid requirements of an actuator according to the invention. The voltage requirements of a particular actuator according to the invention will vary depending on the size of power requirements of the valve and actuator.

[0031] The forgoing are but a few of the many ways in which the present invention may be embodied. The above embodiments are offered for purposes of illustration only and are not limiting. Accordingly, it is intended to protect all subject matter defined by the accompanying claims and equivalents thereof.

Claims

1. An electro-hydraulic actuator comprising:

   an actuator casing;
   a piston/rack means (5) in said casing having walls (25) reciprocating to effect linear movements, said reciprocating walls (25) defining a centre chamber (24) therebetween and two outside chambers (35) inside said casing;
   an output shaft (22) in communication with said piston/rack means (5), said output shaft (22) effecting rotational movements in response to the linear movements of said piston/rack means (5);
   resilient return means (1) in each of said two outside chambers (35) engaging said recipro-

cating walls (25) of said piston/rack means (5) and inner end walls of said casing, said resilient return means (1) biasing said reciprocating walls (25) of the piston/rack means (5) to a closed position;

a pumping means (8);

a primary internal flow path (27) for transferring hydraulic fluid from said pumping means (8) to a first output port (23) and into said centre chamber (24), said hydraulic fluid in said centre chamber (24) causing said piston/rack means (5) to expand in said casing to transmit said linear movements to said output shaft (22); and

a fail-safe solenoid valve system having a secondary internal flow path (28) connecting to and extending from said primary internal flow path (27) to a second outlet port (34) opening into at least one of said outside chambers (35), and a normally closed solenoid valve (29) in said secondary flow path (28) preventing flow through said secondary internal flow path (28);

wherein, upon loss of power to said actuator, said fail-safe solenoid valve (29) opens to thereby cause said resilient return means (1) to force hydraulic fluid ut of said centre chamber (24), through said primary and secondary internal flow paths (27 and 28), into at least one of said outside chambers (35), so that said piston/rack means (5) is returned to a closed position for rotating said output shaft (22).

2. An electro-hydraulic actuator according to Claim 1 further comprising at least one internal guide rod (4) for guiding said linear movements of said piston/rack means in the casing.

3. An electro-hydraulic actuator according to Claim 2 wherein at least one of said internal guide rods (4) contains said first output port (23) from said primary flow path (27); and wherein fluid flowing to and from said primary flow path (27) to said centre chamber (24) flows through said at least one internal; guide rod (4) and said first output port (23) in said internal guide rod (4).

4. An electro-hydraulic actuator according to any one of the preceding claims further comprising a positioning solenoid valve system, said positioning solenoid valve system including

   a tertiary internal flow path (32) connecting to and extending from said primary internal flow path (27) to said second outlet port (34); and

   a normally closed positioning solenoid valve (31)in said tertiary flow path (32) preventing flow through said tertiary flow path (32);

   wherein, to partially close said actuator piston/rack means (5), said positioning solenoid valve (31) is opened by a positioning controller allowing said resilient return means (1) to force hydraulic fluid out of said centre chamber (24) through said primary and tertiary internal flow paths (27 and 32) and into at least one of said outside chambers (35) and to move said piston/rack means (5) to a partially closed position whereby said positioning controller closes said positioning solenoid valve (31).

5. An electro-hydraulic actuator according to Claim 4 wherein said positioning solenoid valve (31) has a smaller flow capacity than said fail-safe solenoid valve (29).

6. An electro-hydraulic actuator according to any one of the preceding claims wherein said piston/rack means (5) is capable of transmitting linear movements into rotational movements of up to 360 degrees for said output shaft (22).

7. An electro-hydraulic actuator according to any one of the preceding claims wherein said pumping means (8) comprises a gerotor positive displacement pump (18).

8. An electro-hydraulic actuator according to any one of the preceding claims comprising

   a push rod (14) for monitoring the position of said piston/rack means (5); and

   a limit switch (13) for stopping pumping of said pumping means (8) when said push rod (14) indicates said piston/rack means (5) is fully open.

9. An electro-hydraulic actuator according to any one of the preceding claims further comprising

   a check valve (11) located at the outlet of the pumping means (8) for preventing backflow into the pumping means (8).

10. An electro-hydraulic actuator according to any one of the preceding claims wherein said output shaft (22) drives a valve.

11. An electro-hydraulic actuator according to any one of Claims 1 to 9 wherein said output shaft (22) drives one of a damper or louvre.

12. An electro-hydraulic actuator according to any one of said preceding claims wherein said resilient return means (1) comprises springs.

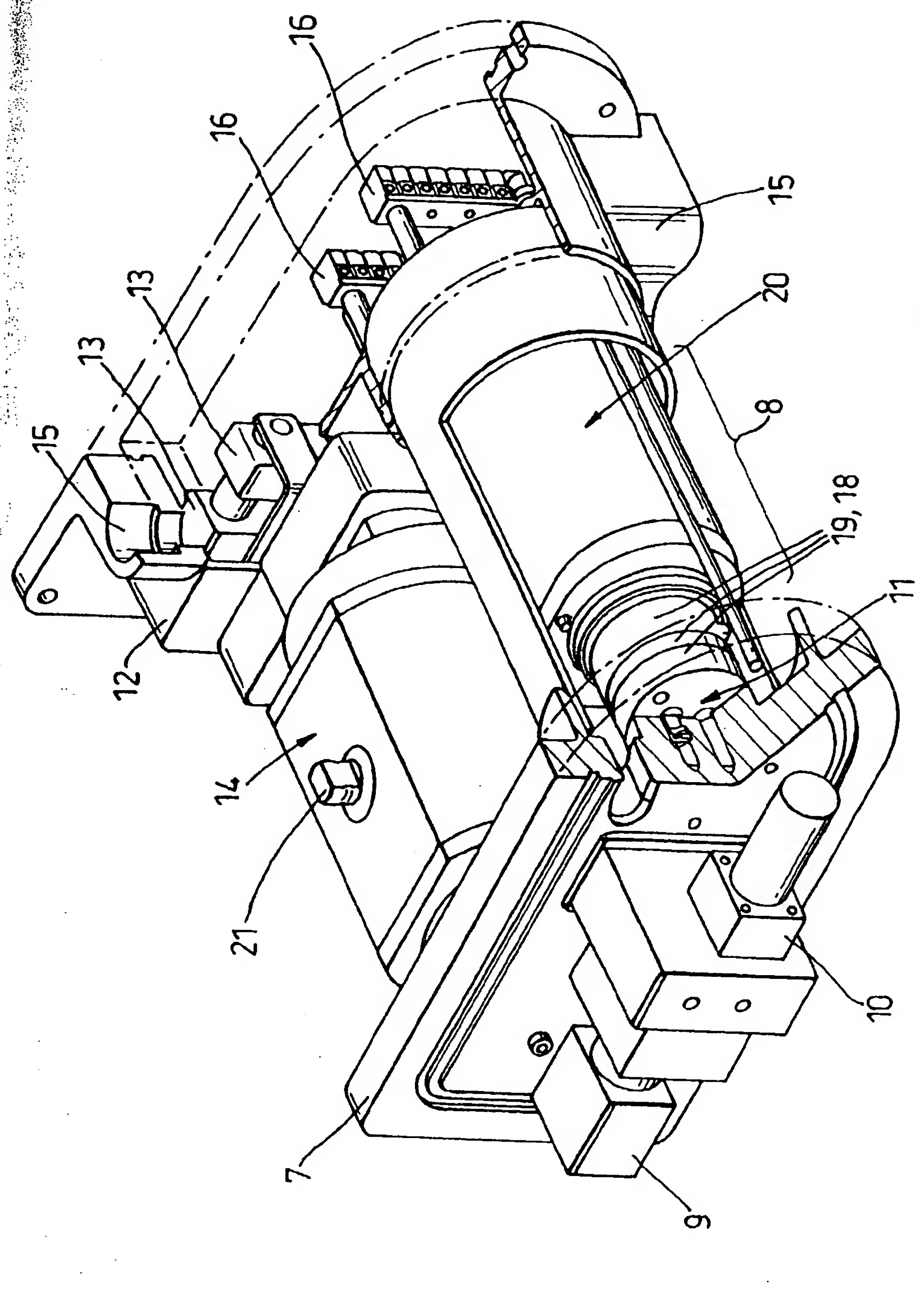

Fig. 1

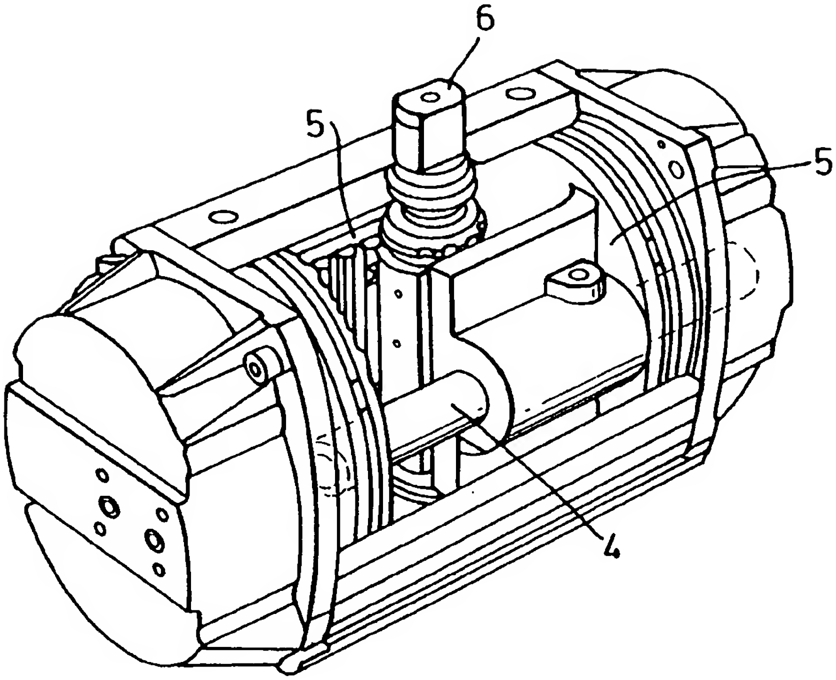

Fig. 2a

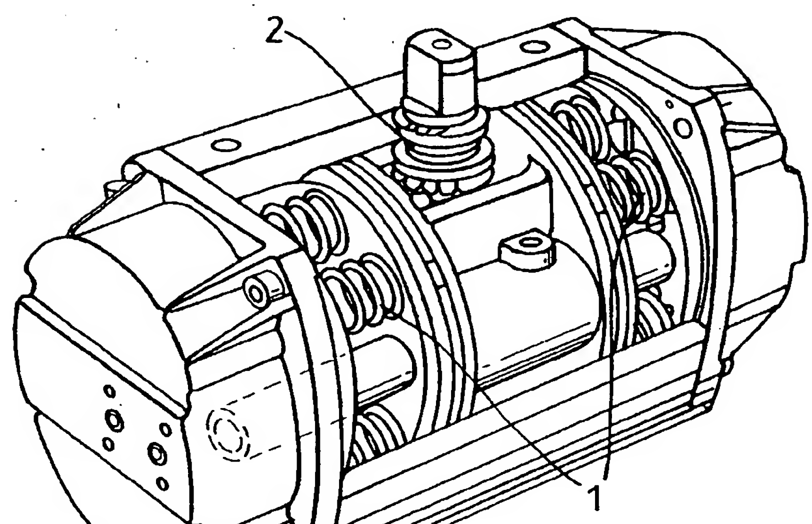

Fig. 2b

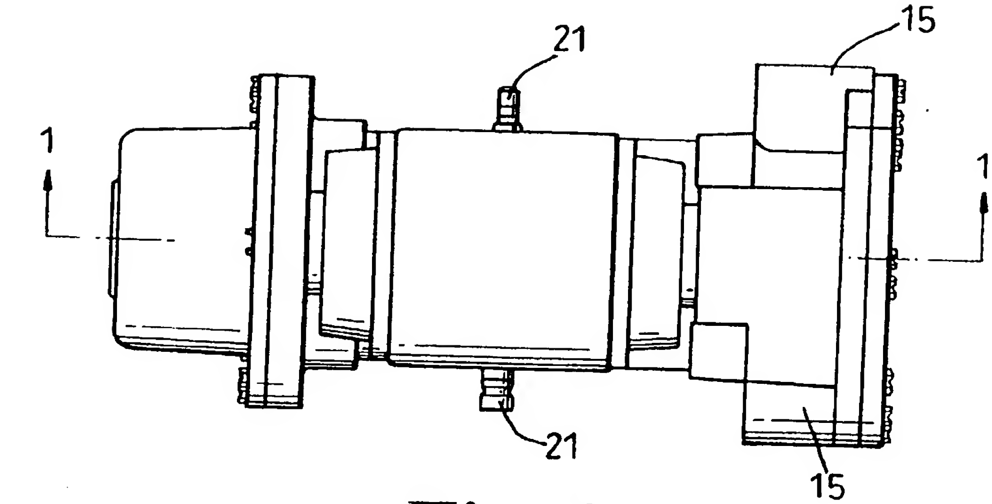
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Fig. 3

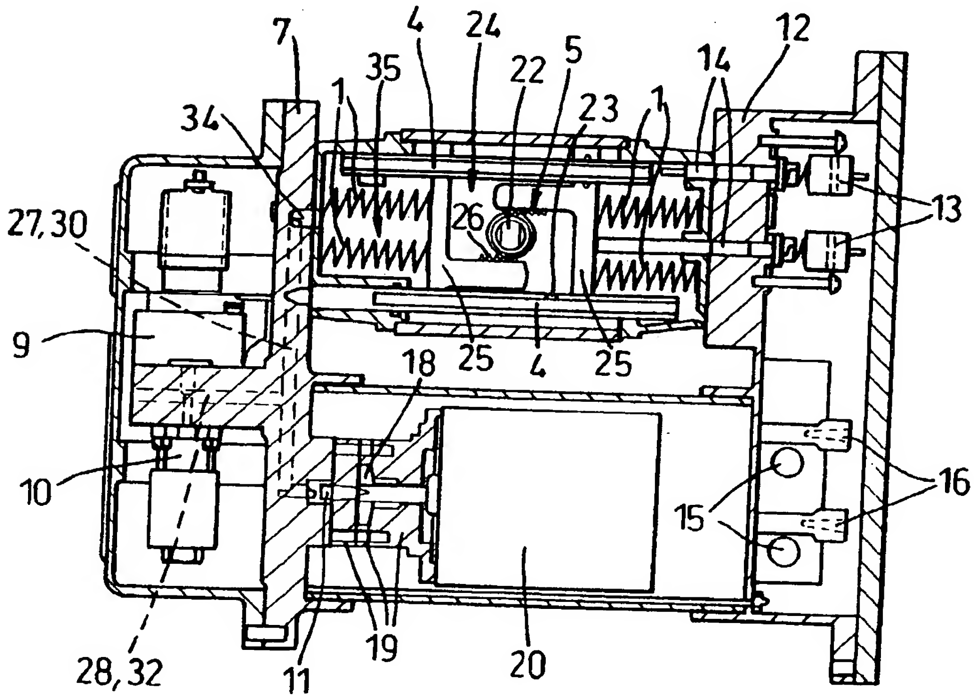
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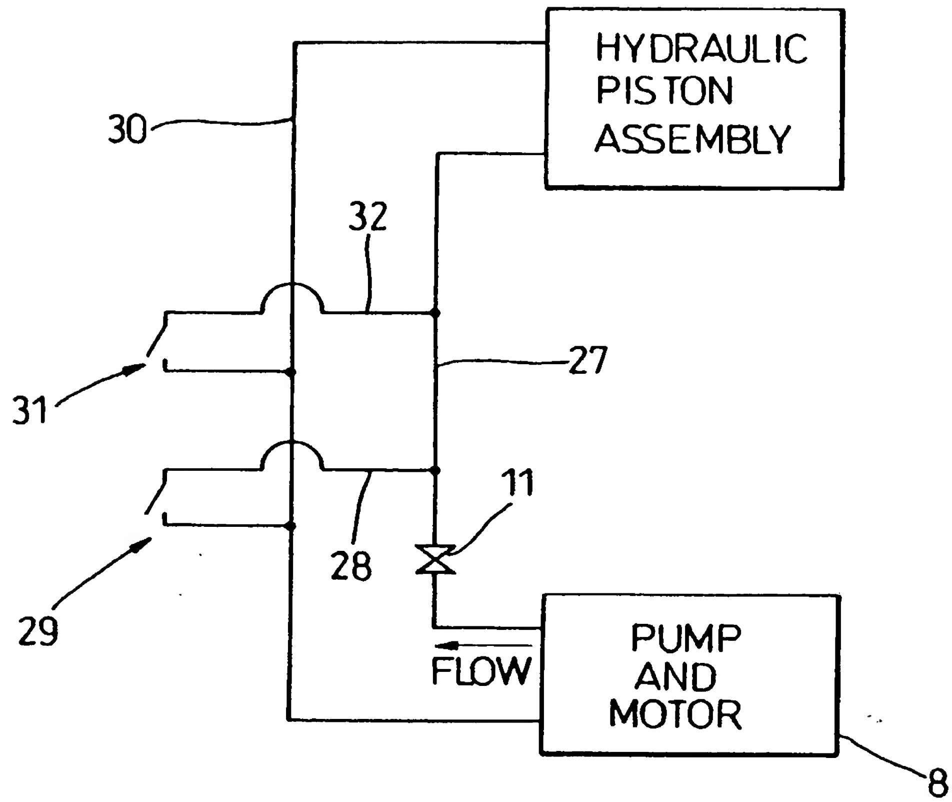
Fig. 4


HYDRAULIC PISTON ASSEMBLY
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32
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31
11
28
29
FLOW
PUMP AND MOTOR
8

Fig. 5

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(54) **Electro-hydraulic actuator**

(57) An electro-hydraulic valve actuator comprising an actuator casing, a piston/rack means (5) in the casing; an output shaft (22) in communication with the piston/rack means (5) for driving a valve, the output shaft (22) effecting rotational movements in response to the linear movements of the piston/rack means (5); resilient return means (1) biasing the reciprocating walls (25) of the piston/rack means (5) to a closed position; a pumping means (8); and a fail-safe solenoid valve system. Upon loss of power to the actuator, the fail-safe solenoid valve (29) opens to thereby cause the resilient return means (1) to force hydraulic fluid out of the centre chamber (24) through the primary and secondary internal flow paths (27 and 28), into at least one of the outside chambers (35), so that the piston/rack means(5) is returned to a closed position for rotating the output shaft (22) to drive the valve.

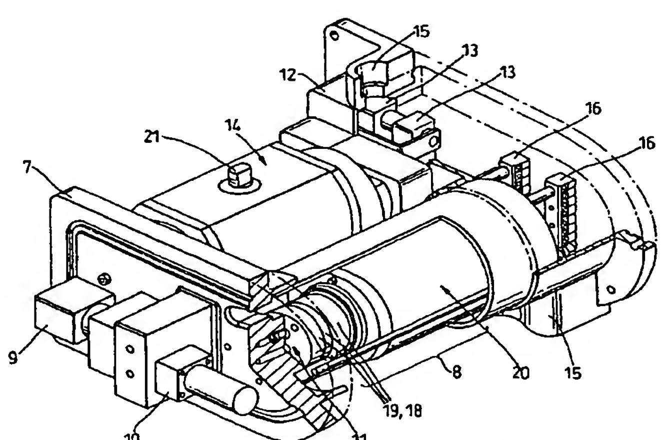

Fig. 1

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 30 9079

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			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			F15B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	1 February 2000	SLEIGHTHOLME, G

CATEGORY OF CITED DOCUMENTS

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